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Framework for approaching the minimum CV(RMSE) using energy simulation and optimization tool

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Abstract

Global warming has become one of the most significant environmental issues. To solve this problem, baseline model has been created by energy simulation to determine the future energy consumption. Meanwhile, reliability analysis needs to conduct between baseline model and existing building. This study aims to develop the minimum coefficient of variance of the root mean square error (CV(RMSE)) framework to improve the reliability of baseline model. The baseline model is considered to be accurate as the CV(RMSE) gets closer to 0%. As a follow-up research, the minimum CV(RMSE) will be used to develop the baseline model by conducting multi-objective optimization.

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Keywords: CV(RMSE), Energy simulation, Optimization tool, Baseline model

1. Introduction

Recently, global warming and climate change has been caused by the increase of the greenhouse gases (GHGs) emissions [1]. Furthermore, the building sector accounts for a large portion of the total energy consumption worldwide [2-4]. Accordingly, the building energy simulation plays an important role in solving these problems. The building energy simulation has several advantages: (i) simulation allows analysts to evaluate the system performance; (ii) simulation is less expensive and less time consuming;

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(iii) simulation makes it easier for analysts to interpret results [4] For these reasons, in previous studies, researchers showed interests in developing the baseline model with the minimum coefficient of variance of the root mean square error (CV(RMSE)). Many previous studies have presented the calculation method [4] and process for achieving the minimum CV(RMSE) [5,6]. Zheng and Brucin [4] examined the calculation methods for achieving the minimum CV(RMSE), such as analytical calibration methods. Analytical calibration methods use lots of input data such as HVAC, zone size, and height. Raftery et al. [6] presented the process for achieving the minimum CV(RMSE) using energy conservation measure analysis. However, these studies have the following limitation. In order to satisfy the standard CV(RMSE) of baseline model using the methods from the previous studies, the calculation process should be conducted manually. Accordingly, it should be repeated until the energy simulation satisfies the criteria. Therefore, this study aims to develop framework for satisfying the minimum CV(RMSE) through optimization process. This study is organized as follow: (i) selecting the target facility; (ii) conducting the energy simulation; (iii) calculating the CV(RMSE); (iv) setting the design variables; and (v) conducting the optimization process.

Nomenclature	
CV(RMSE)	Coefficient of variance of the root mean square error Applied Energy
E_a	Yearly electricity consumption (actual data)
E_s	Yearly electricity consumption (simulation data)
GHGs	Greenhouse gases
GPSPSOCCHJ	Generalized Pattern Search Particle Swarm Optimization with Constriction Coefficient Hooke-Jeeves
KMA	Korea Meteorological Administration
N	Number of data (months)
Y_{au}	Average of actual electricity consumption for a year
$y_{au,I}$	electricity consumption of each month (actual data)
$y_{eu,I}$	electricity consumption of each month (simulation data)

2. Consideration for optimal CV(RMSE)

2.1. CV(RMSE)

The CV(RMSE) is one of the statistic models. Global organizations such as ASHRAE, IPMVP, and FEMP have set their own standards for the CV(RMSE) of the baseline model (i.e. ASHRAE is 20% [5]; The IPMVP is 5%; and FEMP is 10% [5]). The CV(RMSE) can be calculated as follows [7].

$$CV(RMSE) = \frac{\sqrt{\sum_{i=1}^{n}(y_{eu,i} - y_{au,i})^2 /(n-1)}}{\overline{y}_{au}} \times 100 \tag{1}$$

Where, $y_{eu,i}$ is simulation-based electricity consumption of each month, $y_{au,i}$ is actual electricity consumption of each month, y_{au} is an average of actual electricity consumption for a year, and n is the number of data (months).

3. RESEARCH FRAMEWORK FOR APPROACHING MINIMUM CV(RMSE)

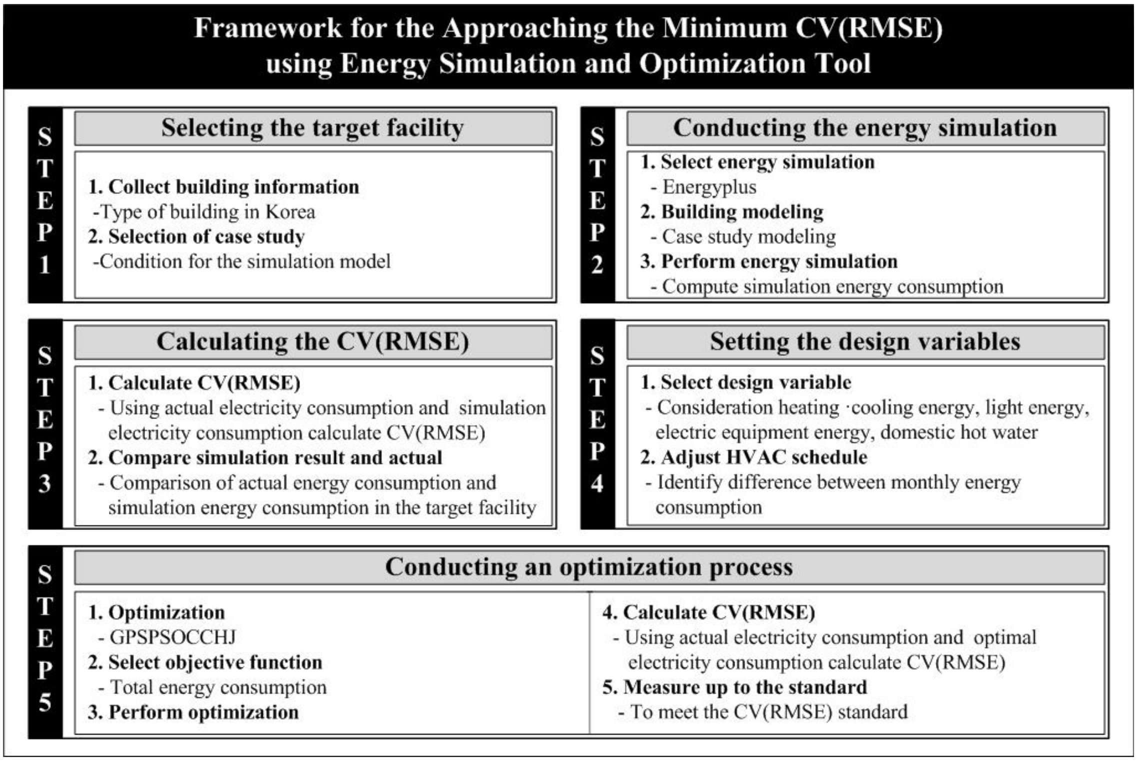

Fig. 1. Research framework of the optimal CV(RMSE)

As shown in Figure 1, the research framework is presented for approaching the minimum CV(RMSE). The research framework is categorized into 5 steps: (i) selecting the target facility; (ii) conducting the energy simulation; (iii) calculating the CV(RMSE); (iv) setting the design variables; and (v) conducting the optimization process.

3.1. Selecting the Target facility

In order to calculate the CV(RMSE), information of the baseline model should be collected such as energy consumption, HVAC systems and so on [7]. After that, the target facility needs to be selected. This study selected 'Y' elementary school as the target facility which is located in Seoul [1].

3.2. Conducting the energy simulation

In order to obtain energy consumption using simulation tool, many researchers selected EnergyPlus among various energy simulations in previous studies [7]. Using energy simulation, this study calculated monthly energy consumption of the baseline model.

3.3. Calculating the CV(RMSE)

Using actual energy consumption and simulation-based energy consumption, the CV(RMSE) was calculated. In order to achieve the minimum CV(RMSE), the gap between an actual energy consumption and simulation-based energy consumption should be minimized.

3.4. Setting the design variables

For approaching the minimum CV(RMSE), this study established the set point of cooling and heating systems as the design variables.

3.5. Conducting the optimization process

For optimization, this study used *Genopt* as optimization tool. *Genopt* provides optimization algorithm called *Generalized Pattern Search Particle Swarm Optimization with Constriction Coefficient Hooke-Jeeves (GPSPSOCCHJ)* [9]. In order to optimize the objective function, this study has set the annual energy consumption as an objective function. Using equation (2), objective function is calculated. In order to satisfy the minimum CV(RMSE), the optimization process was repeatedly conducted.

$$\left| E_s - E_a \right| \tag{2}$$

Where, E_s is simulation-based annual electricity consumption, E_a is actual annual electricity consumption.

4. CASE STUDY

To validate this research framework, this study selected ‘Y’ elementary school which is located in Seoul as the target facility. The CV(RMSE) of ‘Y’ elementary school is manually calculated as 18.20% in terms of the indoor optimal level temperature in Korea Meteorological Administration (KMA). This study selected the heating and cooling set point as design variable. Objective function was set to annual energy consumption of ‘Y’ elementary school.

5. Result and discussion

As shown in Figure 2, actual energy consumption, simulation-based energy consumption (manual), and simulation-based energy consumption (optimization) are compared. As a result, the CV(RMSE) based on the simulation-based energy consumption (optimization) came out to be 13.29%. This indicates that the simulation-based energy consumption (optimization) is closer to the actual energy consumption than the simulation-based energy consumption (manual). Through the optimization process, the reliable energy consumption of baseline model was obtained.

This result of this study has the contribution as follows: (i) the minimum CV(RMSE) is achieved using the proposed research framework; (ii) the minimum CV(RMSE) can be obtained automatically through the optimization process instead of conduction the energy simulation manually and repeatedly. As a result,, the minimum CV(RMSE) can be obtained with less effort and computational burden by using the proposed framework.

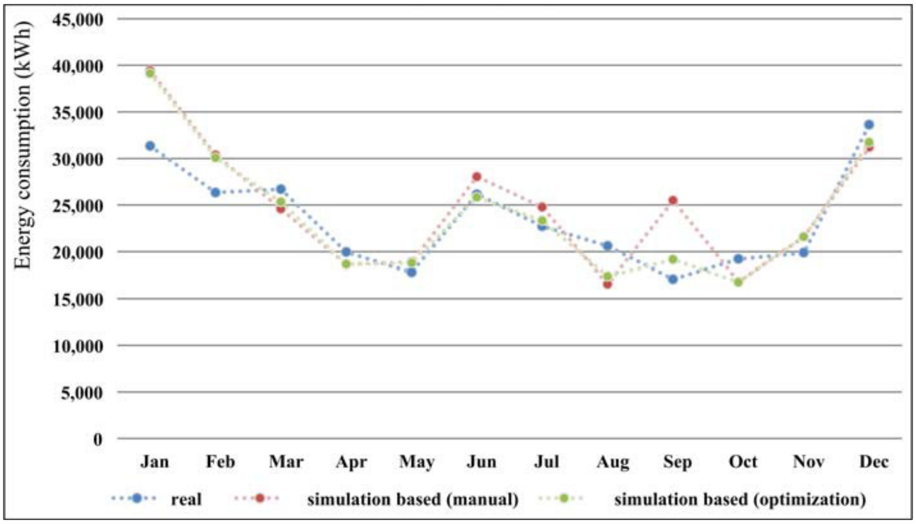

Fig. 2. Comparison of actual and simulation-based energy consumption

6. CONCLUSION

This study aims to develop a research framework for approaching the minimum CV(RMSE) in order to achieve more reliable baseline model. The framework consists of 5 steps: (i) selecting the target facility; (ii) conducting the energy simulation; (iii) calculating the CV(RMSE); (iv) Setting the design variables; and (v) conducting the optimization process. As a result, it was shown that the proposed framework is effective for achieving the minimum CV(RMSE) in an easy way. CV(RMSE) was calculated as 18.20% before optimization, however, it was improved to 13.29% after optimization. This study proposed an effective method compared to the previous studies which requires calculating the minimum CV(RMSE) manually and repeatedly..

This study has limitation in terms of accuracy, as there is a lack of detail in time interval of optimization tool. In the future research, one of the objective functions should be selected as monthly energy consumption for the multi-objective optimization in order to improve the accuracy of the baseline model which can minimize the CV(RMSE).

7. Copyright

8. Acknowledgements

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Biography

Jimin Kim is a graduate research assistant and Ph.D. student at the Department of Architectural Engineering in Yonsei University, Seoul. He is working at the SUStainable COnstruction Management (SUSCOM) laboratory and interested in the following research areas: Sustainable Construction Management and Construction Project Environmental Impact Control.